An Abstract of the Thesis of

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Title: The Effect of Equipment Structure on The Creative Thinking of Young Children in a Problem Solving Situation

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Prior to this investigation few studies had looked at the impact of equipment design on the creative thinking of young children while they solved problems. Nor had previous studies provided support for a clear link between creative thinking and problem solving. An original piece of problem solving equipment incorporating creative thinking skills found in Guilford's **Structure of the Intellect** was designed to test the main supposition of the study. Specifically, the equipment served as a tool to determine if the amount of structure in a problem solving situation would impact the the creative thinking skills young children used as they sought solutions to the problem.

The subjects were 112 middle-class children, aged 4 years, 1 month to 7 years, 5 months. They were randomly assigned to one of four equipment conditions as they were

accepted into the study on the basis of their age and sex. All four conditions systematically varied so that each group had a problem that did not change in substance, but rather in the structure of the problem situation.

The data yielded five scores; four scores of creative thinking that reflected Guilford's work and one score that was a composite. A 2 (age) x 2 (sex) x 4 (condition) MANOVA with time as a covariate was used to analyze the four subscale scores and an ANOVA using the same variables was repeated with the composite score. Separate oneway Scheffe analyses were calculated to examine significant effects where appropriate.

The central conclusion of this study was that young children appear to use more creative behaviors while they problem solve if they are presented with a clearly defined and structured problem that has several alternatives available for seeking solutions. In addition, the study confirmed support for a link between creative thinking and problem solving. Age and sex did not have a major effect on the problem presented in this study; however, minor effects were noticed and discussed.

THE EFFECT OF EQUIPMENT STRUCTURE ON THE CREATIVE THINKING OF YOUNG CHILDREN IN A PROBLEM SOLVING SITUATION

By

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Introduction

The parameters affecting young children's problem solving are not fully understood. Past research has studied various aspects of problem solving that lay a foundation for this study, including descriptive and manipulated variables. However, there has been little investigation of how problem solving equipment impacts the quality of children's thinking while they problem solve. Nor has there been research that specifically documents that creative processes are used during problem solving. This research examines the link between creative thinking and problem solving by exploring how variations of problem solving equipment affect problem solving behaviors indicative of skills outlined in Guildford's **Structure of the Intellect.** Specifically, this study uses problem solving equipment to determine if the amount of structure in a problem solving situation impacts the creative thinking skills young children use as they seek solutions to the problem.

The Foundation of Past Research

During the past twenty years, a number of investigators have studied various aspects of problem solving. These aspects include both descriptive and manipulated variables. The major descriptive variables are age, sex, and socioeconomic status (SES). It is now clear that children's problem solving behaviors change with age (Bem, 1970; Friedman et al., 1971; Klahr & Robinson, 1981; Sibulkin & Uzgris, 1978; Steinberg, 1980; and, Wetsch, Mchamie, Gudwig, & McLane, 1980). The children's sex and their SES are also known to impact the sophistication of their problem solving (Bishop & Chance, 1971; Cooper, 1980; Henderson, 1984; Henderson & Moore, 1980; Johnson & Ershler, 1981; and, Saxe & Stollock, 1971).

The most commonly manipulated variable included in problem solving studies has been play. Prior play experiences with problem solving materials have been found to consistently encourage children to explore materials longer and find more innovative solutions to the problems (Cheyne & Rubin, 1983; Henderson & Moore, 1980; Li, 1978; Pepler & Ross, 1981; Smith & Dutton, 1979; and, Sylva, Bruner, & Genova, 1976).

Research on young children's problem solving behavior has been labeled in many ways. However, when the scoring procedures of problem solving tasks for young children are

examined, the same three thinking skills consistently surface: fluency, flexibility, and elaboration. A fourth, redefinition, is alluded to (Kieren, Kieren, & Henton, 1977; Pepler & Ross, 1981; Sylva, Bruner, & Genova, 1976; and, Vandenberg, 1981). These four skills are the same thinking skills used in Guilford's **Structure of the Intellect** (Guilford, 1965; and, Guilford & Hoepfner, 1971). Guilford calls these four skills creative abilities. The recurring use of the same thinking skills to study problem solving behaviors suggests that many researchers assume that there is a theoretical link between creativity and problem solving. Yet, a direct link has not been established.

An example of a problem solving model designed to combine creative thinking and problem solving, is the Osborne-Parnes model, **Creative Problem Solving** (Parnes, 1967; and, Torrance & Myers, 1970). The Osborne-Parnes model also assumes that there is a link between creative thinking and problem solving (Parnes, 1967). Although creative thinking has been widely studied in the Osborne-Parnes model, the direct link between creative thinking and problem solving has not been studied (Mansfield, Busse, & Krepelka, 1978).

Support for a firm link between problem solving and creative thinking is important if practitioners are to make the best use of creativity literature in order to design and build interactive problem solving equipment which encourages creative thinking. Without the establishment of a direct

link between creative thinking and problem solving, it is not surprising that few studies have specifically looked at the impact of equipment design on the quality of problem solving in young children. To date, research has only been done on more global issues such as environmental design and how training changes children's performance on problem solving and creativity tests (Blank, 1975; Bradford & Endsley, 1980; Cliatt, Shaw, & Sherwood, 1980; Mansfield et al., 1978; Nash, 1981; Thomas & Berk, 1981; and, Turner, 1980).

Although age, sex, SES, global issues such as the impact of environment, and training are important for understanding problem solving in young children; they do not address qualitative issues of equipment design such as equipment's impact on creative behaviors during the problem solving process.

Purpose of This Study

This study was designed to examine the effect of equipment on young children's creative behaviors in a problem solving situation under four different conditions. The equipment incorporated creative thinking components of Guilford's **Structure of the Intellect** in order to document the use of creative thinking skills when children problem solve.

Each of the four conditions used a maze and air pressure techniques. The problem was to move ping pong ball(s) according to the choices available in each condition. These four conditions were:

CONDITION	DESCRIPTION
1. A fixed maze with a fixed pushing device.	1. Maze and one air pressure technique provided.
2. A fixed maze with open pushing devices.	2. Maze and three air pressure techniques provided.
3. An open maze with a fixed pushing device.	3. Construct own maze and air pressure technique provided.
4. An open maze with open pushing devices.	4. Construct own maze and three air pressure techniques provided.

In order to assess the creative behaviors young children exhibit while problem solving with this equipment, scoring procedures were developed after reviewing procedures from prior research in two related areas, creative thinking and problem solving. A definition of terms based on research in these two areas follows.

Definition of Terms

Young children have difficulty using complex processes in sequential patterns. However, they do solve problems in creative ways. In this study, creative thinking, while problem solving, is defined as goal directed behavior that can work toward several possible solutions. Creative

thinking skills are used in this process. The creative thinking skills relevant to this study include:

1.	Fluency	-the ability to produce quantities of ideas.
2.	Flexibility	-the ability to change the mode of response spontaneously or because adaptation is needed.
3.	Elaboration	-the ability to add to ideas already produced.
4.	Redefinition	-the ability to rearrange variables so that a new problem is formed.

Literature Review

Past research on problem solving by young children has produced a foundation for work on specific conditions that affect children's behavior and their solutions to problems. Consistent patterns have emerged regarding the developmental nature of problem solving, the impact of a variety of descriptive variables, and globally manipulated conditions on children's problem solving behaviors. Despite this, there is still a paucity of research focused on identifying guidelines for designing problem solving equipment--- especially problem solving equipment that encourages creative thinking in young children. The purpose of this study is to examine the effect of four systematically varied equipment conditions on young children's creative behaviors while they are solving a problem.

In order to provide the background rationale for this study, relevant literature in four areas will be presented. These include: 1) Guilford's model of creative thinking skills; 2) creative problem solving; 3) selected variables that have been shown to affect problem solving behavior in young children; and, 4) problem solving equipment for young children.

Guilford's Model of Creative Thinking

Guilford's theory, **Structure of Intellect,** describes cognition. One of the areas of cognition is creativity. He views creativity as a cognitive ability that involves seven thinking skills that are continuously variable within all individuals (Guilford, 1965). These skills include:

1. sensitivity to problems - the ability to perceive implications from given information.
2. fluency - the ability to produce quantities of ideas, words, figural symbols, and relationships.
3. flexibility - the ability to change the mode of response spontaneously or because adaptation is needed.
4. elaboration - the ability to add to ideas already produced.
5. redefinition - the ability to rearrange variables using existing information to form a new definition.
6. penetration - the ability to see more aspects of a problem which enables you to continue working or resist the tendency to close or to stop.
7. originality - the ability to give unique, clever responses and to make remote associations. (Guilford & Hoepfner, 1971).

Two educational psychologists, have worked extensively with Guilford's model and have designed separate creative

thinking measures based on it. Torrance's instrument, the **Torrance Test of Creative Thinking**, has been widely used for over 25 years to measure the four creative thinking skills of fluency, flexibility, elaboration, and originality (Torrance, 1962).

Meeker's instrument was published in 1975. The test is based on Guilford's **Structure of the Intellect** model and is called the **SOI.** It measures several components of Guilford's model and the creative thinking section assesses the four thinking skills of fluency, set change (flexibility), transformation (redefinition), and originality (Meeker & Meeker, 1975).

Creative Problem Solving

Some researchers assume a theoretical link between Guilford's creative thinking skills and problem solving. Beginning in the 1960s, educational psychologist Sidney Parnes collaborating with advertising executive Alex Osborne designed a formal problem solving model specifically incorporating Guilford's theories about creative thinking (Parnes, 1967). The model became known as **Creative Problem Solving.** It consists of five steps which include:

1. Defining or finding the problem;
2. Finding facts about the problem;
3. Generating ideas that might work;
4. Selecting and testing ideas; and,
5. Finding a way to use the solution (Parnes, 1967).

Each step is characterized by a divergent and convergent phase in which creative and logical skills are used. However, creative thinking skills are emphasized. In fact, the model is used extensively to develop creative thinking skills in a wide age range of students (Mansfield et al., 1978; Shanklee & Amos, 1984; and, Torrance & Myers, 1970).

Using any training model applicable to a wide age range requires that the training be adjusted to the developmental needs of the target audience. The **Creative Problem Solving** model is designed so that each adaptation incorporates practice on learning various steps of the process and on applying creative thinking to a problem situation. For example, adults and high school students learn the process and apply strategies throughout (Mansfield et al., 1978), while elementary school students work on skills and then learn the process (Mansfield et al., 1978; and, Torrance & Myers, 1970). Most of the work with older students is highly verbal and requires the ability to sequence.

Shanklee and Amos (1984) reported a pilot study using the process in a simplified form with kindergarten children. Shanklee and Amos' adaptation uses concrete experiences that encourage language development. Each separate activity presents part of the process. It is designed so that the teacher always leads children to applying the steps of solving a problem.

Mansfield et al. (1978) feel that part of the success of the **Creative Problem Solving** model appears to be due to the wide variety of ways creative thinking is used in solving problems. Additionally, the model's success across wide age ranges appears to be due to maintaining its integrity while adapting to developmental differences of the students who use it.

To date, most research on creative problem solving training uses Guilford's model as the theoretical base. As such, these studies use some variation of the assessment tools designed by Torrance or Meeker to measure creative thinking (Mansfield et al., 1978). A research tool that specifically assesses creative problem solving does not yet exist. Rather, creative thinking skills are used as a base and inferences are drawn about how these apply to problem situations. The consistent use of creative thinking skills to assess creative problem solving training suggests many researchers accept a theoretical link between creativity and problem solving.

Selected Variables Known to Impact Problem Solving in Young Children

Age. Regardless of children's problem solving ability, they must first recognize that a problem exists. Without recognition, solutions are not sought. There is some evidence that sensitivity to problematic situations, as well as complexity of search strategies, is developmental and

improves with age. Although gradual, a rapid jump occurs sometime between the ages of four to seven. The exact age of the jump and of the skills used varies from study to study. However, perceptual discrimination, cognition, and language skills are central themes in this age change (Bem, 1970; Klahr & Robinson, 1981; McClinton, 1981; Sibulkin & Uzgris, 1978; Steinberg, 1980; Vlietstra, 1980; and, Wertsch et al., 1980).

The work of Bem (1970); Sibulkin and Uzgris (1978); Vlietstra (1980); and, Wertsch et al. (1980) highlight the role of perception in children's problem solving abilities. Bem (1970) studied the effect of verbal and visual instruction on four-year-old children as they worked on a colored block building task that required patterning. Regardless of instruction type, children were more successful with the task when they perceived the end-state.

Sibulkin and Uzgris (1978) also found that perceiving the end-state and key elements of how to get there affected problem solving behavior. They demonstrated easy and difficult problems to four-year-olds. The tasks involved using a ball in a maze. Irrelevant hand gestures were systematically used in the demonstration. Children ignored the irrelevant stimuli on the easy tasks. However, they imitated the irrelevant gestures while attempting the difficult tasks. Once the difficult task was mastered, the children spontaneously deleted the irrelevant gestures. These results suggest that until the children mastered the

task, the key elements eluded them. Their inability to perceive the essential elements affected their perception and attention.

Vlietstra (1980) examined the issue of relevant elements in problem solving from a developmental perspective. She showed the same visual cues to four-year-olds, eight-year-olds, and college students. Irrelevant and relevant cues were mixed into a series of cards. Four-year-olds made many errors and showed little improvement. They attended to both relevant and irrelevant cues. Eight-year-olds initially attended to all cues as well, but they did learn to ignore irrelevant ones. The college students sorted the cues immediately. Vlietstra's results suggest that there is a developmental change in the ability to perceive and attend to cues that aid problem solving.

Wertsch et al. (1980) found that even direct modeling and verbal encouragement would not help young children solve problems if they were not developmentally ready to perceive the problem at hand. Wertsch and his colleagues used a colored block puzzle using sequence with parent-child dyads. The children ranged in age from two-and-one-half to four years of age. The two-and-one-half and young three-year-old children consistently put the puzzle together in random sequence. The demonstrated sequence was not used until children were close to four years of age--regardless of parent cajoling. When given the same directions, younger

and older children choose different aspects of the problem to work on and used cues in different ways.

In addition to perception of the problem and understanding its end-state, the use of other cognitive skills increases with age. Klahr and Robinson (1981) gave four-year-olds, five-year-olds, and six-year-olds a variation of the tower of Hanoi problem. Detailed analysis showed that older subjects could complete more steps of a process, use sequence better, and describe their efforts in more detail. Younger children tended to perseverate more often and to use fewer search strategies. Steinberg (1980) used a computer based problem with five-year-old and seven-year-old children and found these same phenomenon.

Language development also appears to effect problem solving. Problem solving studies that have looked at children's language abilities have found that younger children have difficulty describing their actions as they find solutions to problems. The concept of <u>vertical decolage</u> (action is more advanced than verbal expression) describes this finding (Klahr & Robinson, 1981). McClinton's study (1981) also confirms this finding. She found that if materials are removed, preschoolers are better able to describe their actions. They appeared to have trouble talking and doing at the same time. However, seven-year-old children are able to talk about their discoveries as they make them.

Thus, a clear developmental change occurs as children develop perceptual, cognitive and language skills. This occurs in both boys and girls. However, differences do exist between the sexes as they work on the problem at hand.

Sex. Many problem solving studies with younger children look at the play behaviors of the subjects. Many of these studies have also analyzed play behaviors for sex differences. Both boys and girls found solutions, but they appeared to do so differently. For example, Cheyne and Rubin (1983) found that boys solved problems more rapidly, especially when the problem required spatial relationship skills.

In another study, held in a discovery oriented-classroom that promoted problem solving, Johnson and Ershler (1981) found that preschool boys and girls played with materials in different ways. Boys engaged in more functional play, while girls engaged in more social play. Additionally, Johnson and Ershler found that when a needed material was unavailable, the type of transformation children made on materials varied by sex. Boys were likely to substitute objects or pretend to do so. Girls were more likely to change the theme of their play. These subtle differences may color the way problem solving behavior is recorded.

Socioeconomic status. In addition to sex and age, SES may also effect the way children problem solve. In a classic essay that outlines research on the socialization of

problem solving, Bee (1971) describes the differences of low and middle SES mothers. Generally, low SES mothers were less attentive and supportive than mothers from middle income families when their children were engaged in problem solving situations. Udwin and Shmuker (1981) also found this pattern. These studies suggest that lower income families do not socialize children to apply the skills they have to a problem solving task. In addition, low SES children may not be socialized to problem solve on their own.

The literature on curiosity is related to these SES studies on problem solving. Several curiosity studies show that supportive middle SES parents who model curiosity, exploration, and manipulation of materials tend to have children who follow suit (Bishop & Chance, 1971; Henderson & Moore, 1980; Moore & Bulbulian, 1976; and, Saxe & Stollock, 1971). Curiosity about and exploration of materials may be a key to learning about how materials work. Knowledge about the attributes of materials has a clear impact on problem solving. Research on prior play experience, for example, has shown that prior exploratory experience with materials helps children problem solve more effectively as well as in more innovative ways.

Prior play experiences. A critical condition for creative problem solving in young children is exploratory play time with the materials prior to problem solving sessions. Play time appears to allow children to discover

how materials work. While problem solving, young children consistently produce more potential solutions differing in nature and are more goal directed when they are familiar with the materials. Free play, as opposed to training, appears to increase creative thinking.

Much of the information on prior play experience comes from research surrounding tool use. An early tool design for use with toddlers, incorporated the use of a lever to rotate a "lazy susan" (Koslowski & Bruner, 1972). Another example is the stick and lure problem, designed by Sylva et al. (1976). In each case, the problem was solved faster and with more creative solutions when children had time to play with the materials (Cheyne & Rubin, 1983; Pepler & Ross, 1981; Smith & Dutton, 1979; Sylva et al., 1976; and, Vandenberg, 1981).

Environmental conditions. While prior play facilitates creative thinking and problem solving, so do certain physical and emotional environments. The studies reviewed in this section focus on creativity. However, in each case, a key component of the Osborne-Parnes **Creative Problem Solving** model has also been incorporated.

The physical environment can encourage creative thinking and problem solving. Nash (1981) studied the impact of spatial arrangements in a classroom on learning. Four and five-year-old children increased their creativity scores when materials where placed to encourage combinations, synthesis, and evaluation. Nash's findings

suggest that spatial organization can impact the way children use materials and their creative thinking.

An emotional climate that can enhance creative thinking can also be provided by teachers. In two different studies, teachers were trained to ask thoughtful questions that used higher level thinking based on Bloom's taxonomy and so encouraged kindergarten and preschool children to produce several options. Creativity levels increased in both studies, particularly the ability to produce ideas (Cliatt et al., 1980; and, Turner, 1980).

Thomas and Berk (1981) studied the effect of teacher control upon six-year-old and seven-year-old children. The children were divided into three groups. One group was placed in a teacher-directed classroom. A second group was placed in a child-centered classroom, while the final group worked toward consensus with the teacher on the amount of choice the children could exercise. Thomas and Berk found that the moderate balance of structure and freedom of the consensus group was an effective way to increase children's creativity.

Problem Solving Equipment for Young Children

Given the solid foundation of research focused on selected variables and global conditions that affect creative thinking and problem solving behaviors in young children, it is surprising that so little is known about the

design of equipment that will encourage the same behaviors. This is especially surprising given the emphasis in the literature on providing practice with creative thinking in problem situations.

Only two studies which remotely looked at the specific characteristics of problem solving equipment were found. One study examined the use of form and color in 36 three- through eight-year-old children (Hoekstra & McDaniel, 1969). The subject's ability to use color and form in meaningful ways progressively increased with age. The youngest children could not focus on both elements at the same time, while the oldest children could.

The second study compared the use of two-dimensional and three-dimensional tasks when studying original thinking in preschoolers (Moran, Milgram, Sawyers, & Fu, 1983). As expected, three-dimensional problems that can be manipulated were found to be more appropriate for young children. This finding reaffirms the traditional early childhood education practice of having real objects for young children to use.

Both equipment studies are consistent with the general literature on developmental trends of problem solving by young children. However, neither sheds much light on the conditions that will specifically facilitate creative thinking in problem solving situations.

Although research is scant, criteria for equipment design has been developed. Nelson and Sawada (1975) published an essay that outlined guidelines for developing

good problems for young children. Although they were interested in mathematical problem solving, not creative thinking, many of their criteria would appear to be valid for designing problem solving equipment in general. Their criteria included:

1. The problem should be of significance mathematically.

2. The situation in which the problem occurs should involve real objects or obvious simulations of real objects.

3. The problem situation should capture the interest of the child either because of the nature of the materials, the situation itself, the transformations the child can impose on the materials, or because of some combinations of these factors.

4. The problem should require the child to make moves or transformations or modifications with or in the materials.

5. Whenever possible, problems should be chosen which offer opportunities for different levels of solutions.

6. Whatever situation is chosen as the particular vehicle for the problem, it should be possible to create other situations which have the same mathematical structure.

7. Finally, the child should be convinced he can solve the problem and should know when he has a solution for it (Nelson & Sawada, 1975, pp. 28-29).

Although not all problem solving research with young children labels test behaviors in the same way, creative thinking skills surface in scoring procedures of various problem solving devices (Cheyne & Rubin, 1983; Goodman, 1979; Kieren et al., 1977; Li, 1978; Pepler & Ross, 1981

Smith & Dutton, 1979; Sylva et al., 1976; and, Vandenberg, 1981). For example, fluency is labeled as the number of ideas produced and flexibility as the number of innovative solutions and/or the variety of search strategies children use. Vandenberg also incorporated a complexity score in his tool; something akin to the creative thinking skill, elaboration. A fourth creative thinking skill is also alluded to in several studies. This fourth skill is variously called "defining their own problem" or "transformation." Upon examination, it is the creative thinking skill of redefinition (Johnson & Ershler, 1981; and, Harter, 1975). The scoring procedures for these studies reflect Guilford's **Structure of the Intellect** even if they do not use his labels.

Even though problem solving research uses a variety of tools which have not been specifically labeled as assessing creative thinking, creative thinking skills are often assumed to be incorporated into the tools. If labels consistent with Guilford's work were coupled with Nelson and Sawada's criteria to produce equipment, the equipment is likely to be theoretically and practically sound.

Summary

Even though there is little research on the characteristics of problem solving equipment or on the documentation of creative thinking being used while young

children problem solve, a great deal is known about problem solving in general. Guilford's **Structure of the Intellect** provides a theoretical base for studying the creative thinking skills that are assumed to be used in problem solving. Although not always labeled as such, four of the skills identified by Guilford--fluency, flexibility, elaboration, and redefinition--have successfully been used to assess problem solving behaviors in young children. However, since the assumed theoretical link between creative thinking and problem solving has not been solidified, the current problem solving research has not yet been focused toward the establishment of equipment guidelines that might encourage young children to use creative behaviors while solving problems.

If a research tool is designed to substantiate the assumed link between creative thinking and problem solving and/or study aspects of how problem solving situations impact thinking skills, the findings from past problem solving investigations would be helpful. Past research suggests that a wide variety of factors need to be addressed in any future study. For example, it is clear that young children's problem solving ability increases with age. Also, boys and girls appear to have different styles, although both are effective problems solvers. In addition, parents and teachers can model and/or design environments that encourage children to find innovative, effective solutions to problems.

Methods

Subjects

The subjects for this study were 112 four-year-old through seven-year old children. They were drawn from the 1985, 1986, and 1987 class registration lists of the Portland Children's Museum and were randomly assigned to one of four groups based on age and sex.

The museum population. The museum is sponsored by the Portland, Oregon Public Parks and Recreation Department. It is a small children's museum that offers interactive exhibits and classes. According to museum records, the age range of the children coming to the museum are from birth through the elementary school years. However, the average age of the child visitor is four years. The children and parents who use the museum, typically live in the Portland metropolitan area and are from a wide range of socioeconomic and ethnic groups, but tend to be middle-class to upper-middle class (R. Bridgeford, personal communication, January, 1985).

The museum is known as a community resource that offers interdisciplinary programming in the arts and humanities. Many of the programs also provide conceptual experiences that mesh science and technology with the arts and humanities. Museum surveys indicate that parents who enroll

their children in museum classes do so because they are interested in providing enrichment experiences for their children in these areas in addition to regular school programming (R. Bridgeford, personal communication, January, 1985).

<u>Sample population</u>. Based on a parent questionnaire, the families who participated in this study appeared to be representative of the museum population at large. For example, 75% of the parents hold jobs that are included in the middle-class and upper-middle class occupation lists designed by Hollingshead and Redkich (1958). Also, as museum records indicate, the subjects were from a wide range of Portland metropolitan neighborhoods, representing 26 of the 34 Portland zip codes and eight of the 13 outlying area zip codes listed in the 1987/1988 Portland, Oregon telephone directory.

Approximately 14% of the children came from ethnic or racial minorities. The groups that were represented included: Black, Chinese, East Indian, Hispanic, Japanese, and Native American. However, all subjects spoke English at home as their major language.

Also, all but one child was enrolled in a school program. (This child was one of the youngest subjects and the parents elected to provide enrichment classes in lieu of a private preschool program). In addition to school enrollment, 80.4% of the parents enrolled their children in

classes at the museum or other similar community programs two or more times a year.

Selection and assignment of subjects. The 1985, 1986, and 1987 museum class catalogs were used to notify parents of a research project sponsored by the museum. Interested parents indicated willingness for their children to participate in the study on class registration forms (see Appendix A). All interested parents were sent a questionnaire that asked for background data on their child such as birth date, sex, and occupation of parents (see Appendix B). Six rounds of solicitation (375 families) were needed to complete the full complement of subjects.

As subjects were identified, information from the parent questionnaires was used to randomly assign subjects to one of four conditions on the basis of age (4 years, 1 month to 5 years, 8 months and 5 years, 9 months to 7 years, 5 months) and sex. The assignment of the subjects by age and sex into the conditions is shown in **Table 1** (see **Table F-1** in Appendix F for a detailed listing).

Table 1

Subject Assignment

	Condition 1		Condition 2		Condition 3		Condition 4		
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	
<u>Age</u> years/months 4/1-5/8	7	7	7	7	7	7	7	7	
<u>Age</u> years/months 5/9-7/5	7	7	7	7	7	7	7	7	
Totals	14	14	14	14	14	14	14	14	112

The four conditions systematically varied in the way the equipment could be used. These variations are detailed in the instrument section.

Instrument

The instrument was specifically designed for this investigation. A description of the instrument, how it was developed, and notes about the scoring procedures are presented below. They are followed by comments about validity and reliability.

Description. The instrument has four systematic variations that change the amount of structure in a problem solving task. It consists of a maze that requires the use

of air pressure techniques to move ping pong balls from a fixed entry to four fixed exits.

Variation	Description
1. Fixed maze with a fixed pushing device.	The child can move the ping pong ball(s) through the fixed maze with a fixed entry and 4 fixed exits. One piece of air pressure equipment (a hairdryer) is provided to facilitate the ball motion.
2. Fixed maze with open pushing devices.	The child can move the ping pong ball(s) in a maze that is fixed as in variation one. The equipment options provided to facilitate the ball motion include a straw, bellows and a hairdryer.
3. Open maze with a fixed pushing device.	The child can move the ping pong ball(s) in any maze pattern of their choice. However, to facilitate problem solving, a fixed entry and four exits are set. Only one piece of air pressure equipment (a hairdryer) will be provided to facilitate the ball motion.
4. Open maze with open pushing devices.	The child can move the ping pong ball(s) as outlined in variation three and use equipment as outlined in variation two.
All variations	Each variation also has two trays. One tray holds nine ping pong balls and the other holds three blocks and four inclines that are used to direct the ball flow.

For the purposes of this study, the variation numbers are labeled condition one, two, etc., from this point (see Appendix C for photograph of each condition).

Development. The instrument is an extension of a museum exhibit prototype field tested in 1984 at the Oregon Museum of Science and Industry. The original was designed by the early childhood education team at the science museum. The investigator was a member of that team. The current variation was designed and pilot tested by the investigator in the spring of 1985 in a Portland area preschool and a kindergarten. Adjustments in the equipment were made to insure that it was sturdy, functional, appropriate, and interesting for children in this age range (see Appendix D for pilot test observation notes and sample maze constructions).

Scoring procedures. The scoring procedures resulted from a combination of information gathered during pilot testing, observations made during data collection, definitions of creative behavior, and scoring techniques reported in the literature review. They specifically measure four creative thinking skills--fluency, flexibility, elaboration, and redefinition. A composite score, called total is also calculated.

Observations of behavior were used to record the data. The testing sessions were video taped to assist in accurately scoring the observations. Details about the

scoring procedures and a score sheet are found in Appendix E.

Validity. The creative thinking skills from Guilford's **Structure of the Intellect Model** are used as a basis for the scoring procedures. These same skills are often incorporated into problem solving models. The Osborne-Parnes **Creative Problem Solving** model is one example of a problem solving paradigm that relies on Guilford's framework. As such, the scoring procedures have face validity.

Specific content validity also exists for components of the scoring procedures. Torrance (1962) and Meeker and Meeker (1975) have established that some creative behaviors require higher level thinking and are rarer than others. Both of these investigators credit rare behaviors by designing scoring guidelines that weight less typical responses.

Problem solving research with young children also uses a similar tactic. For example, Vandenberg (1981) found that when preschool-aged children used tools to solve problems, their behavior varied a great deal with respect to complexity and elaboration. To account for this, he designed weighted scores to credit children's efforts with higher level thinking. Based on the research of the Meekers, Torrance, and Vandenberg, the elaboration and redefinition scores are weighted in this study.

Not all problem solving behaviors are so complex. Two research teams who have used materials with young children have found simple variations in the number and type of ideas that children generate (Kieren et al., 1977; and, Sylva et al., 1975). Both teams counted these variations equally. Torrance and the Meekers' procedures also count simple variations the same way. Based on the scoring procedures of these instruments, this study treated behaviors indicative of fluency and flexibility equally.

In addition to scoring the behaviors, some accounting for length of time spent on task was necessary. Researchers disagree on how time affects problem solving. For example, based on exploratory studies, Friedman et al. (1971) recommend that open ended tasks not be timed for young children. However, when Kieren et al. (1977) asked children to solve a variety of social and mathematical problems, the children generated many ideas in limited time segments. Since there is no agreement on the issue of time limits in the literature, the subjects were limited to a reasonably long length of time (15 minutes), but were free to stop before their time limit was over. The time spent working was noted.

<u>Reliability</u>. Being a new instrument, no previous reliability ratings were available. However, as an observation based tool, inter-rater reliability is critical. Eight raters were used to score the data. One was the investigator and the other seven were teachers from Portland

Public Schools (grades pre-kindergarten through two) who were interested in observational techniques. After the investigator trained the seven raters, they independently scored eight subjects each for a total of 56 video tape segments. The investigator then independently scored the same tapes. The overall inter-rater agreement for this first scoring was 89.37%. The individual agreement rates were: fluency, 93.29%; flexibility, 84.29%; elaboration, 80.72%; redefinition, 95.39%; and, total score, 93.18%.

All differences were resolved by the investigator and the respective rater through discussion about the written scoring procedures. After study, one part of the elaboration section that scored the use of blocks and inclines was found to be difficult to score accurately. A recording matrix that detailed the use of the blocks and inclines eliminated the discrepancies.

After these joint sessions, the remaining subjects (56) were scored twice by the investigator. If discrepancies existed, the tapes were viewed again by the investigator to resolve the differences. As a result, each tape was scored at least twice.

Procedure

After the subjects were assigned to a condition, they were individually tested and video taped in a quiet room at the museum. One examiner was used throughout. Parents

brought their child, but were not present unless it was necessary for rapport. When necessary, parents were asked to sit quietly in the room.

Introduction of material. Each child was introduced to the materials in the same way. The introduction allowed the subjects to explore the attributes of the materials. The examiner said:

> "I have a game to play with you. It is called chutes and pushers. Part of the game is to find out what kinds of things these toys will do. Another part of the game is to make balls move in these chutes. Let's see what the toys will do first, then you can make the balls move."

A free play period with the materials followed, lasting approximately 10 minutes. Using casual and non-directive conversation, the examiner made sure that each child realized that the chutes fit together to form a maze, that the air pressure equipment could be used to move balls, and that the blocks and inclines could be used to direct the balls.

Problem solving protocol. Immediately after the warm up session, the problem solving began. The examiner said:

> "Now, I have a problem for you to solve."
>
> Condition One: "I'll give you a maze that looks like this (fixed maze) and this pusher (the hairdryer). How might you move balls from here (entry) to these pockets?"
>
> Condition Two: "I'll give you a maze that looks like this (fixed maze) and all these pushers (hairdryer, bellows, and straw). How might you move balls from here to these pockets?"
>
> Condition Three: "I'll give you these chutes so that you fit them together (open maze). There is only one rule. The first chute goes here (entry).

You can use this pusher (the hairdryer) to move balls to these pockets. How might you do that?"

Condition Four: "I'll give you these chutes so that you can fit them together (open maze). There is only one rule. The first chute goes here (entry). You can use all these pushers (hairdryer, bellows, and straw) to move balls to any of these pockets. How might you do that?"

Stated in All Conditions: "Now it is time for you to play the game alone while I watch. I'll set the timer so you can have a long turn (15 minutes)". No probes were given while the subjects used the materials. When the subjects appeared to be done or when 15 minutes was past, the examiner said, "Is there any thing else that you would like to try?" Taping would continue if the 15 minutes was not up and would stop if it had past.

Results

The analysis had two parts; preliminary analyses to assist in preparing the data and the main analysis to test the effects of the independent variables and their interactions on the dependent variables. The independent variables included: age, sex, condition, and their interaction effects. The dependent variables included: fluency, flexibility, elaboration, redefinition, and a total of the other four measures. Post hoc comparisons using Scheffe's oneway analysis tests were applied where appropriate and presented with the results of the main analysis.

Preliminary Analyses

In order to prepare the data for analysis, three preliminary analyses were necessary. The first was to test for the equivalency of the mean age in each condition within the two age groups. The second was to determine if the amount of time subjects used to solve the problem had a significant effect on the outcome measures. The last analysis was a study of the correlation between the dependent variables.

Age groups. The subjects were divided into two age groups, a younger age group (4 years, 1 month to 5 years, 8 months) and an older group (5 years, 9 months to 7 years, 5 months). Subjects within each of the age groups were assigned to one of the four conditions. It was not possible to match the subjects in each condition beyond their general age group and sex. As a result, it was necessary to determine if the mean ages of each condition within the two age groups were equivalent prior to the main analysis. Two oneway analysis of variance tests were used to determine these equivalencies. No significant differences were found among either age group. The mean ages of both age groups are listed by condition in **Table 2.**

Table 2

Mean Age by Condition

Condition	Younger Age Group (years/months)	Older Age Group (years/months)
1	4/9	6/5
2	4/8	6/5
3	5/1	6/4
4	5/1	6/5
All	5/0	6/5

Time. The literature review suggested that the amount of time that subjects spend on a problem solving task might influence the scores they receive. Keeping this in mind, the time each subject spent was noted so it could be

determined if time should be used as a covariate in the main analysis.

The data yielded five scores. The first four scores are independent of each other and the fifth was a total of the other four. Recognizing the total score was dependent on the other four scores, a regression analysis was used to measure the relationship of time and the total score. A significant relationship was found, $r = .2944$, $p = .001$. Since the total score was dependent on the other four scores it was likely that time affected one or more of the other four measures. As a result, time was used as a covariate in the main analysis.

Correlation of the dependent variables. The instrument designed for this study is a measure of creative thinking with four subscales and a total score that is a composite of the other scores. Since all of the measures are creative thinking scores and one of the five scores is a composite of the other four scores, the scores are likely to be related to one another. Using Pearson's correlation method, a correlational table was generated for the dependent variables and confirmed several significant coefficients (see **Table 3**).

Since all but two of the dependent variables were significantly correlated (elaboration/flexibility and redefinition/elaboration) and the literature review suggests that the independent variables may interact with the

dependent variables, the main analysis needed to control for their possible interactions.

Table 3

Pearson Correlation Coefficients
for the Dependent Variables

	Fluency	Flex.	Elab.	Redef.	Total
Fluency	-----				
Flex.	.3208 p = .001	-----			
Elab.	.4659 p = .001	.1897 p = .023	-----		
Redef.	.0264 p = .391	.2257 p = .008	.0137 p = .443	-----	
Total	.6960 p = .001	.5422 p = .001	.7574 p = .001	.5011 p = .001	-----

Analysis for Main Effects

A 2 (age) x 2 (sex) x 4 (condition) multivariate analysis of variance test with time as a covariate was applied to the four creative thinking subscales scores of fluency, flexibility, elaboration, and redefinition. Since the fifth score (total) is linearly related to the the other four scores by virtue of being a composite, a separate 2 (age) x 2 (sex) x 4 (condition) univariate analysis of

variance test with time as a covariate was applied to the total.

The multivariate F for the main effects on the four subscales approached significance, $F(4, 92) = 2.31$, $p = .064$. The univariate F for the main effects for the total score was significant, $F(3, 95) = 6.22$, $p = .014$. The findings associated with the individual independent variables follow.

Condition. The main effect of condition was of particular interest in this study. The multivariate F for the main effect for condition on the four subscales was significant, $F(3, 95) = 4.16$, $p =.001$. Examination of the univariate tests associated with condition revealed three of the four scores on the subscales were significant. They were: fluency, $F(1, 95) = 5.62$, $p = .001$; flexibility, $F(1, 95) = 9.92$, $p = .001$; and, elaboration, $F(1, 95) = 2.87$, $p = .041$. The univariate F for the total score was also significant, $F(1, 95) = 4.43$, $p = .006$.

Post hoc comparisons using Scheffe's oneway analyses were calculated for the conditions. The post hoc comparisons revealed that four out of the five scores appeared to be affected by condition. They included: fluency; flexibility; elaboration; and, total. The redefinition scores did not appear to be affected by condition.

For fluency, the mean score in Condition Two was significantly higher than the mean score in Condition One ($p = .01$).

For flexibility, the mean scores in Condition Two and Four were significantly higher than the mean scores in Conditions One and Three ($p = .01$).

For elaboration, the mean score in Condition Two was significantly higher than the mean score in Condition Three ($p = .10$).

For the total score, the mean score in Condition Two was significantly higher than the mean score in Condition One ($p = .05$) and significantly higher than the mean score in Condition Three at ($p = .10$).

Even though Condition Two was not significantly different from all conditions on all measures with the Scheffe analyses, examination of the mean scores by condition suggests that the highest mean scores were generally found in Condition Two (see **Table 4**). The Scheffe analyses found two exceptions to the generalization that Condition Two appeared to have the most positive effect on scores. The exceptions are in the scores of flexibility and redefinition. Conditions Two and Four appeared to have an equivalent effect on flexibility while redefinition did not appear to be significantly affected by any of the conditions.

Table 4

Mean Scores by Condition

	Condition			
	1	2	3	4
Score				
Fluency	8.82	11.36	9.86	9.71
Flexibility	2.29	3.57	1.71	3.61
Elaboration	5.50	7.89	4.93	5.93
Redefinition	2.04	1.72	2.46	2.36
Total	18.64	24.54	18.96	21.61

Age. Although the multivariate tests for the main effect of age were not significant, examination of the univariate F's revealed that there was one significant difference for age associated with the fluency score, $F(1, 95) = 4.44$, $p = .038$. After studying the mean fluency scores for the two age groups, (younger, 9.13 and older, 10.75) it is clear that older subjects were more fluent than younger subjects.

Sex. The multivariate tests for the main effect of sex were not significant, however examination of the univariate F's revealed significance sex differences associated with redefinition $F(1, 95) = 3.92$, $p = .051$ and, the total scores $F(3, 95) = 6.24$, $p = .014$.

The mean scores for redefinition by sex were: boys, 2.78 and girls, 1.50. The mean scores for the total score by sex were: boys, 22.71 and girls, 19.16. The direction of

the means indicates that boys had higher scores than girls on both measures.

Interaction effects. No significant interaction effects surfaced in the multivariate tests. However, examination of the univariate F values show that for the score of redefinition, there was a significant difference for the interaction of age and sex, $F(1, 95) = 6.94$, $p = .01$.

Post hoc comparisons using Scheffe's oneway analyses were calculated for the mean age by sex redefinition scores (younger boys, 3.73; older boys, 1.82; younger girls, .75; and, older girls, 2.25). The analysis revealed one significant difference with the younger boys having significantly higher mean redefinition scores than the younger girls ($p = .01$).

Time. Finally, time was a significant covariate for fluency ($t = 2.294$, $p = .004$), and the total score ($t = 2.494$, $p = .014$) with elaboration approaching significance, ($t = 1.85$, $p = .068$). This indicates that the longer subjects spend working on the problem, the higher their fluency, elaboration and total scores are likely to be.

Discussion

Summary

The purpose of this study was to examine the effect of equipment structure on young children's creative behaviors in a problem solving situation. The equipment was especially designed for the study to elicit and record behaviors indicative of the creative thinking skills found in Guilford's **Structure of the Intellect.** Prior to this study there had been limited research providing a direct link between problem solving and creative thinking. Even fewer studies specifically looked at the impact of equipment design on creative thinking of young children while problem solving.

The subjects were 112 children, aged 4 years, 1 month to 7 years, 5 months. They were selected from the class lists of the Portland Children's Museum in Portland, Oregon, and were generally from middle-class homes. The subjects were randomly assigned to one of four conditions, as they were accepted into the study, on the basis of their age and sex. All four conditions were variations of a maze that had one fixed entry point and four fixed exits. The four conditions systematically varied so that each group had a problem that did not change in substance, but rather in the structure of the problem situation.

The subjects were individually tested using a standard protocol. The problem solving sessions lasted up to 15 minutes and were video taped for later scoring. The data yielded five scores; four scores of creative thinking that reflected Guilford's work (fluency, flexibility, elaboration, and redefinition) and a composite.

Using age, sex, condition, and interaction effects as independent variables; a 2 (age) x 2 (sex) x 4 (condition) multivariate analysis of variance test with time as a covariate was used to analyze the four subscale scores and an univariate analysis of variance test using the same variables was repeated with the composite score. Separate oneway Scheffe analyses were calculated to further examine the effects where appropriate.

The amount of structure in a problem solving situation was found to impact the subjects' creative thinking scores. The condition that appeared to most enhanced creative thinking scores, Condition Two, had a fixed maze and several alternatives available for finding solutions to the problem.

The central conclusion of this study is that young children use more creative behaviors while they problem solve if they are presented with a clearly defined and structured problem that has open alternatives available for seeking solutions. This conclusion holds true for fluency, elaboration, and the composite score. In addition, the study confirmed support for a link between creative thinking and problem solving.

A minor variation and extension of the central conclusion surfaced for the flexibility score. Both the fixed and open-maze with alternative strategies (Conditions Two and Four) had an equivalent effect on flexibility scores. Another of the outcome measures, redefinition, deviated from the central conclusion and did not appear to be affected by any of the conditions.

The variables age and sex did not have a major effect on the problem presented in this study; however, minor effects were noticed. With respect to age, the data suggested that older children were more fluent than younger children. The relationship between sex and other variables was not clear in the main analysis. However, the univariate and post hoc analyses for the redefinition and total scores suggested minor sex differences. Possible explanations for the lack of clarity over the effect of sex as well as their implications for future research are outlined in detailed in the following discussion section.

One last factor was related to some of the scores. This factor involved the time children spent problem solving. Not surprisingly, children who spent a longer amount of time working with the equipment were likely to get more done. Specifically, when children spent more time working, they had higher fluency, elaboration, and total scores.

Discussion of the Results

The primary statistical analysis used in this study was a multivariate analysis of variance test. This test generates an overall multivariate F-value and univariate F-values for the dependent variables. When the multivariate F-value is not significant, the univariate F-values are often not examined.

In this study, one overall multivariate F-value was generated for the four dependent variables and it closely approached significance, $F(4, 92) = 2.31$. $p = .064$. Three of the four univariate F-values associated with it were significant. An univariate F-value was also computed for the composite score, which was linearly related to the dependent variables. The F-value for the composite score was significant as well, $F(3, 95) = 6.22$, $p = .014$.

Recognizing that the multivariate F-value closely approached significance, three out of four of the univariate F-values associated with it were significant, and the univariate F-value for the composite score was significant; a more detailed examination of the results is appropriate.

Further study might shed some light on why the multivariate F-value only approached significance, while all but one of the univariate F-values were significant. Additional examination may also clarify some of the differences associated with the redefinition scores. In

particular, a review of the relationships between the independent variables and the outcome measures may be helpful.

There were three independent variables in this study: condition, age, sex, plus their interaction effects. The effect of particular interest, condition, was generally clear while the effect of age and sex were less clear.

Condition. The main analysis found that condition had an impact on four of the five dependent variables. The application of oneway Scheffe analyses helped undercover Condition Two as the condition with the most consistent positive impact. Even though the Scheffe tests did not find a significant difference in all cases, examination of the mean scores by condition generally revealed that the outcome measures were highest in Condition Two.

One minor exception to the generalization that Condition Two had the most positive effect on scores was found for the score of flexibility. Conditions Two and Four had an equivalent effect on the score of flexibility. Condition Two was structured so that the subjects had the greater number of choices within the two fixed-maze options. Condition Four was structured in the same way for the two open-maze options. It may be that a large number of choices are conducive to flexible thinking, but that too many choices (as in Condition Four) may not be as supportive of fluent and elaborative thinking.

A second exception for the generalization that Condition Two had the most positive effect on scores was found when examining the redefinition scores. Redefinition scores did not appear to be affected by any condition, yet were affected by sex and the interaction of age by sex. In an attempt to understand this finding, a more detailed discussion will be undertaken when the independent variable of sex is considered.

Age. The main analysis did not not discover any significant effects for age. However, the univariate values did reveal one significant age difference associated with fluency. Generally, older children had consistently higher fluency scores than younger children. Such an age difference is noteworthy since fluency accounted for 47% of the total creative score in this study. Fluency was also significantly and positively related to the children's total creatively score ($r = .6960$, $p =.001$) and had the strongest covariate relationship with time ($t = 2.94$, $p =.004$) when compared with all the other creativity scores. Furthermore, it was under Condition Two that children appeared to have the highest fluency scores (see **Table 5**).

Because of the apparent importance of fluency for children at this age, it is logical that fluency rather than other aspects of creative thinking revealed a significant age difference. This age difference indicates that children

become more fluent in producing ideas with age as they solve problems.

Table 5

Mean Scores for Fluency by Age and Condition

	Age	
	Younger	Older
Condition		
1	8.36	9.29
2	10.43	12.29
3	8.36	11.36
4	9.36	10.07

Sex. The variable of sex produced some puzzling findings. Reviewing the univariate F-values in the main analysis, sex significantly affected redefinition scores. Overall, boys had higher redefinition scores than girls. However, a significant age by sex interaction associated with the redefinition scores further complicated the simpler sex difference finding.

Scheffe test results for redefinition means revealed the only significant age by sex difference to be between younger boys and younger girls. This post hoc finding suggests that boys develop redefinition skills earlier than girls and may also indicate that redefinition skills are influenced by developmental differences between boys and girls.

Caution must be made in accepting the above finding without question since a number of issues can be raised with

respect to the children's redefinition scores in this study. Only a small number of children exhibited redefining behaviors suggesting that although there are minor sex differences associated with redefinition, they may not be a critical factor in the overall creativity of young children. In fact, in this study, redefinition contributed only 10.5% to the total score.

The minor importance of the sex difference findings was further illuminated upon examination of the score weighting procedures. Historically, creativity and related instruments weight rare or unusual behaviors more heavily than typical behaviors (Meeker & Meeker, 1975; Torrance, 1962; and, Vandenberg, 1981). The instrument designed for this study did as well. Fluency and flexibility were treated equally with each new incident being given one point; new incidents of elaboration were given two points; and, new redefinition incidents were given three points. Since the subscales were weighted differentially, the weighting needs to be considered when comparing the subscale scores since they are not directly comparable in value.

When making tentative interpretations about redefinition, it is important to keep the following four factors in mind:

1. Redefinition was the least frequently displayed attribute of the four creative thinking skills in this study.

2. When children demonstrated redefinition, they tended to use it more than once.
3. Since the redefinition score was weighted more heavily than the other scores, the score is skewed when used for comparison purposes.
4. Age may influence redefinition with the maturation process assisting children in the consistent use of redefining behaviors. It is conceivable, for example, that younger children may actually be exhibiting flexible equipment use or exploration when displaying redefining behaviors.

These four factors are not only important for keeping the minor effect of sex on the redefinition scores of this study in perspective, but may also be important for future research with this instrument. It may be that weighting redefinition behaviors should be evaluated. It may also be that redefinition scores need to be reclassified as flexible or exploratory behaviors. If the redefinition scores are changed in either of these two ways, a very different depiction of sex differences may emerge.

The univariate F-values in the main analysis also revealed another sex difference associated with the total creativity score. The sex differences associated with the total score were less puzzling than those associated with redefinition. Overall, boys had higher total creative thinking score than girls. However, examination of the

means associated with the total score revealed that this difference held true for all conditions except Condition Two (see **Table** 6). Under Condition Two, both boys and girls had equivalent total creativity scores. This finding appears to support the efficacy of Condition Two in facilitating children's creative thinking skills.

Table 6

Mean Scores for Total by Sex and Condition

	Sex	
	Boys	Girls
Condition		
1	21.79	15.50
2	24.79	24.29
3	20.50	17.43
4	23.79	19.43
All	22.71	19.16

Relating the Results to Research and Theory

The results of this study are related to research and theory in three areas: 1) the relationship of the results to prior research; 2) the relationship of the results to theory; and, 3) the utility of the instrument designed for this study.

Relationship of the results to prior research. Past research on problem solving in young children has generated developmental and global information about how young children solve problems. The studies were not specifically

designed to measure creative thinking while children solved a problem. As a result, the past studies did not learn how equipment might impact the quality or amount of creative thinking that children exhibited when they searched for solutions (Hoekstra & McDaniel, 1969; and, Moran et al., 1983).

Using four experimental situations centered around one piece of problem solving equipment, the current study controlled for the variables of condition, age, and sex. The study also accounted for the time subjects spent working. Each of the independent variables, plus time, have some reference to past studies, either building upon or confirming them.

The data in the current study indicate there may be an optimal condition (Condition Two) for encouraging the use of creative thinking skills in a problem solving situation. This condition involves a well defined problem with a clear structure providing several alternative strategies for seeking solutions. Condition Two had positive effects on all the creative thinking skills except redefinition. It also appeared equivalent to the effect on flexibility in Condition Four.

Heretofore, the traditional creativity literature has not indicated what type of equipment might enhance either general or specific creative thinking skills in a problem solving situation (Hoekstra & McDaniel, 1969; and, Moran et al., 1983). Identifying the parameters of equipment makes a

new contribution and will allow future research to examine problem solving situations in closer detail.

When looking at the overlay of age on the four experimental conditions, an age difference surfaced for fluency scores. Older children appeared more fluent than younger children. This is consistent with the developmental trend of problem solving scores improving with age as reported in past research (Klahr & Robinson, 1981, McClinton, 1981; Steinberg, 1980, Vliestra, 1980; and, Wertsch et al., 1980).

The controls of the study also allowed the investigator to look at sex differences in the four conditions. The outcome was less clear for sex than it was for condition and age. Two differences related to sex were found. One difference was associated with redefinition and the other was associated with the total score. For redefinition, boys had higher scores than girls in all conditions. Boys also appeared to develop redefinition skills earlier than girls. For the total, boys also had higher scores than girls, except in Condition Two where their scores were comparable.

At first glance, the sex differences appear to be in conflict. One probable interpretation comes from past research (Cheyne & Rubin, 1983; and, Johnson & Ershler, 1981). The ability to use the skill of redefinition with the instrument designed for this study may favor spatial relationship skills. The work of Cheyne and Rubin and of Johnson and Ershler, consistently found that boys exhibit

better spatial relationship skills than girls do in problem solving settings. If spatial relationships were a significant factor in this study, the aptitude did not appear to effect girls' overall ability to use creative thinking skills in Condition Two. In fact, given this condition, the girls' total scores were comparable to boys. Condition Two, therefore, may have helped girls overcome this difference with boys.

This later interpretation is consistent with sex difference in past research that find both boys and girls are effective problem solvers, but tend to have different strengths and/or styles (Cheyne & Rubin, 1983; and, Johnson & Ershler, 1981). However, a caution needs to be issued regarding any interpretation about sex differences found in this study since there were only a small number of children displaying the redefining behaviors associated with the sex differences.

Finally, the variable of time spent working was used as a covariate in the current study. Past research has not identified a consistent relationship between time spent working and problem solving (Friedman et al., 1971; and, Kieren et al., 1977). The current study found a significant relationship between time and some of the scores. These included fluency and the total score, with elaboration approaching a significant relationship. It would appear that children who spend more time working are likely to use the skills of fluency and elaboration more often. Since

fluency and time had the strongest relationship, it also seems likely that the amount of time a problem solver works will impact the number of ideas generated. Based on these findings, future problem solving research should account for the variable of time in some fashion.

Relationship of the results to theory. This study was in part, designed to focus on the theoretical question: do children use creative thinking skills in problem solving situations? Affirming this question would support a firm link between creative thinking and problem solving.

Guilford's **Structure of the Intellect** is built on the premise that creative thinking is made up of several cognitive skills that can be used in many situations including problem solving. The Osborne-Parnes **Creative Problem Solving** model is one example of a problem solving model that is specifically designed to train people to draw upon their creative thinking skills, as described by Guilford, while they engage in problem solving. To date, research supporting this link has followed the logic of: if creative thinking skills improve when people learn to use creative problem solving models, it is because the creative problem solving models employ creative thinking skills (Cliatt et al., 1980; Mansfield et al., 1978; and, Turner, 1980).

This study used the more direct logic of: if children exhibit behaviors indicative of creative thinking in a problem solving situation, there is a link between creative

thinking and problem solving. The strong tie between theory, instrument design, and analyses results in confirmation of the direct logic. The confirmation provides support for a link between creative thinking and problem solving.

The utility of the instrument. Before this study, a research tool specifically designed to measure creative thinking while subjects solve a problem did not exist. The literature review indicated that most research was with older children and used paper and pencil measures to assess the efficacy of creative problem solving training, but not creative thinking in problem solving situations (Cliatt, et al., 1980; Mansfield et al., 1978; and, Turner, 1980). The effort to examine creative thinking of young children in problem solving situations was further hampered by not using manipulative instruments even though the literature suggested that a manipulative instrument would be likely to yield better and higher quality information about problem solving in young children (Moran et al., 1983; and, Nelson & Sawada, 1975).

Using information from past studies, the instrument for this study was designed to be manipulative and individual, two criteria of good instruments for young children (Moran et al., 1983; and, Nelson & Sawada, 1975). By usual standards, the instrument appears to be a useful research tool to study young children's creative thinking within a problem solving context.

The instrument for this study specifically measured creative thinking by documenting the behaviors young children exhibited in a problem solving situation. As part of the development process, solid and high initial overall inter-rater reliability was established (89.37%). The behaviors that the children exhibited were consistent with prior research in both problem solving and creative thinking so there is face validity. Content validity exists for the scoring procedures as well, since they were based on other well established instruments.

Suggestions for Further Research

Several questions arose from undertaking this study. One set of questions centered around the use of the instrument for examining the creative problem solving process. A second set had it's focus on the scoring procedures of the instrument. A third set of questions centered around how children might respond to the research instrument in other settings.

Creative problem solving. The search for an instrument to specifically document and measure creative problem solving is elusive. One reason is that creative problem solving is a process and as such is difficult to document. The instrument designed for this study has the potential to fill this void.

Identifying parts of the creative problem solving process was not done in this study because it did not enhance the direct purpose of the study, namely examining the effect of equipment on creative thinking in a problem solving situation. However, an ad hoc analysis of the video tapes could be done in order to study the process the subjects used and such a process could be compared to the Osborne-Parnes model. If insufficient information about some steps of the process is uncovered, additional research using the tool from the current study as a basis for asking children to demonstrate their thoughts could be done. For example, in reviewing the video tapes, the one component of the process that may be lacking is evaluation. Questions could be devised to direct children to select their favorite solution or perhaps one that they would share with a friend and then show the examiner why it was selected.

Scoring procedures. The post hoc study of sex differences highlighted potential problems with the scoring procedures: labeling redefining behaviors and weighting the resulting score. One potential problem is that weighting may skew the data and make it difficult to compare scores directly. The historical precedence of weighting rare or unusual behavior may have been helpful in examining creativity; however, this methodology may not be practical when applying creative thinking to problem solving. More study of this issue may be productive for other investigators.

The second potential problem is that developmental processes may influence children's redefinition skills. What has been labeled redefining behavior in younger children may actually be something else, e.g., flexibility or exploratory behavior. The use of developmental and/or information processing theories to guide additional study of how development influences behavior may be useful. Further examination of how the creative thinking skill of redefinition relates to problem solving may also be constructive.

Other settings. During the process of data collection questions for three other studies using the instrument arose. One question was, given a similar research setting, would children use the instrument differently if they solved the problem with a friend? Another question was, if the instrument was in a classroom setting where children could repeatedly use the instrument, would their scores increase over time and/or would the various conditions show the same results? The third question is, what would age differences look like if a group of eight-year-old and nine-year-old children were compared to the current data?

Implications for Practical Application

The practical implications of this study cover two arenas. One is application in classrooms and the other is applications in museum settings.

Classroom settings. Teachers often set up an activity with the general goal of fostering creativity. Traditionally, most preschool and some kindergarten teachers do this by providing open-ended activities with no stated goal (Cliatt et al., 1980; Nash, 1981; and, Turner, 1980). As children enter the primary grades, open-ended tasks decrease. The open-ended tasks often are replaced with activities of increasing structure because of a perceived need to develop basic skills through sequenced, skilled-based education models (Thomas & Berk, 1981; and, Torrance & Myers, 1970). If one goal of education is to develop problem solving skills and creative thinking as part of basic skills, neither of these traditional modes may be an effective method. Rather, young children throughout these grades, would benefit from a balance of clearly outlined tasks and problems while promoting the use of alternative strategies to complete the tasks and solve the problems.

Museum settings. Young children usually are brought to museum settings by parents or teachers to enhance and enrich their home and/or school experiences. A stated goal of many museums, particularly children's museums, is to provide creative and cultural experiences for visitors (Lewin, 1984; and, Lynn, 1985). The conclusions of this study could assist exhibit designers in reaching their goals. Exhibits incorporating an intriguing problem while seeking a balance of structure and alternatives, are more likely to entice the

child visitor to use the exhibit and thus foster creative thinking while learning what the exhibit has to offer.

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Appendices

Appendix A

Subject Recruitment Notice

Subject Recruitment Noitce

Portland Children's Museum is happy to announce that they are participating in a research study on creative thinking and problem solving. All children between the ages of four and seven who register for it's classes will be eligible to participate. Those children who do join the study will be videotaped while solving game-type problems. All families will remain anonymous. If you wish to participate, your class registration form will automatically qualify you for the selection process. If you do not wish to be considered, please note this on the registration form.

Appendix B

Parent Letters and Questionnaire

Parent Questionnaire

Child's name ____

Birthday ____

Sex ____

Parent's name ____
address ____
____
phone ____

Father's occupation ______________________________________

Mother's occupation ______________________________________

Racial or ethnic origin of child

Caucasian ______
Asian ______
Black ______
Native American ____
Hispanic ____
Other (specify) ______________________________

Are parents of the same ethnic or racial background?

yes ____ no ____

What is the primary language spoken in the home? ___________

Does your child attend a school?

yes ____ no ___

How long has the child been in school? ______ years

How often do you enroll your child in community enrichment programs like the Children's Museum classes?

First time _____
Once a year _____
Twice a year _____
Three or more times a year _____

If so, where have you enrolled your child? _________________
____

What types of programs has your child participated in at the above institution?

_____ Drama/Puppetry
_____ Art
_____ Music
_____ Science
_____ Physical Education _____ Other ______________________

Will you be able to bring your child to the museum for a data collection session? The session will take about 30 minutes.

Check the time that is most convenient:

Saturday____________________________

Sunday____________________________

Weekday____________________________

Do you need to work around a vacation schedule?

Yes _____ No _____

If yes, when ____

Date

Dear Parent,

Your child's name was selected from the class registration files of the **Portland Children's Museum** as a possible candidate for a research study on children's learning. The museum staff has agreed to help me locate over 100 children for the study. The project is part of my research for a Ph.D. in Child Development from **Oregon State University.**

The purpose of the study is to observe young children as they solve a problem with a museum-type exhibit game that I have designed for the study. The game has four versions based on the same theme: blowing ping pong balls through chutes. It is best described as a large floor maze. Children blow the balls from the starting point to any of several end points with air pressure devices such as a straw, a bellow, or hair dryer. I've field tested the game with over 50 four, five and six year children and it delighted all of them. The game is short, fun and has no wrong answers. Hopefully it will tell me a great deal about how equipment effects the way young children solve problems.

If you agree to have your child participate in the study, I will ask you to do two things. The first is to fill out the enclosed consent form and questionnaire and then return it to me at the museum. The second is to bring your child to the museum for a 30 minute play session. The play session will be video taped for later study. The tape will be used for research purposes only. In return for your help, I will mail you an abstract of the completed study that will summarize my findings. If your child wishes, he or she may keep one of the ping pong balls.

If you have questions you can reach me at home (245-2653) or at work (280-6196). Or, you can leave a message for me at the museum (248-4587).

I hope you will agree to participate. If you do, please fill out the attached consent form and questionnaire. I'll be in touch to confirm an appointment. If you do not wish to participate, please indicate so on the consent form and return it. I would appreciate all replies by (date) so that I can set up schedules.

Thank you for your time,

Rebecca Severeide

_____ Yes, I agree to have my child to participate in the research study sponsored by the **Portland Children's Museum** on children's learning and problem solving.

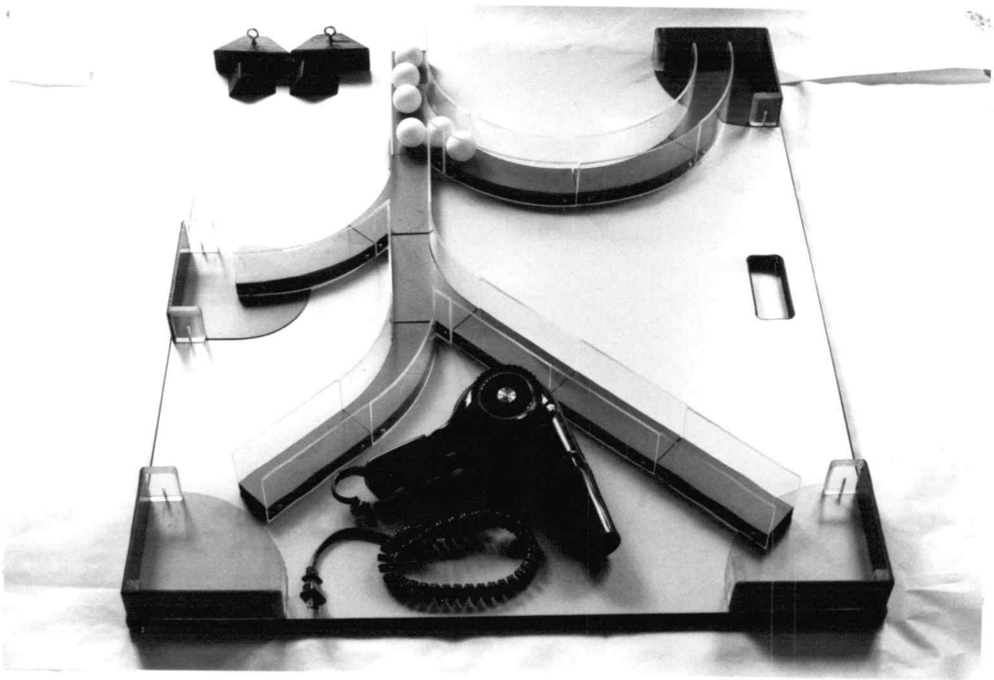
I will fill out the enclosed forms and bring my child to the museum for a short video taped play session.

_____ No, I would not like my child to participate in the research study.

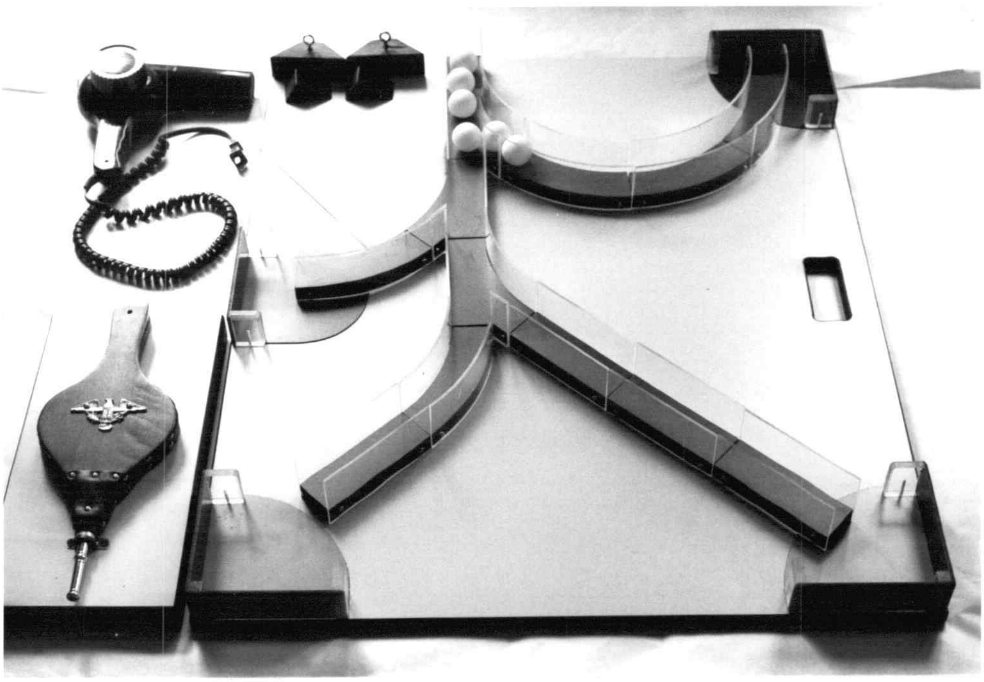
Parent's Name____________________________
Address__________________________________
____
Parent's
signature________________________________

Appendix C

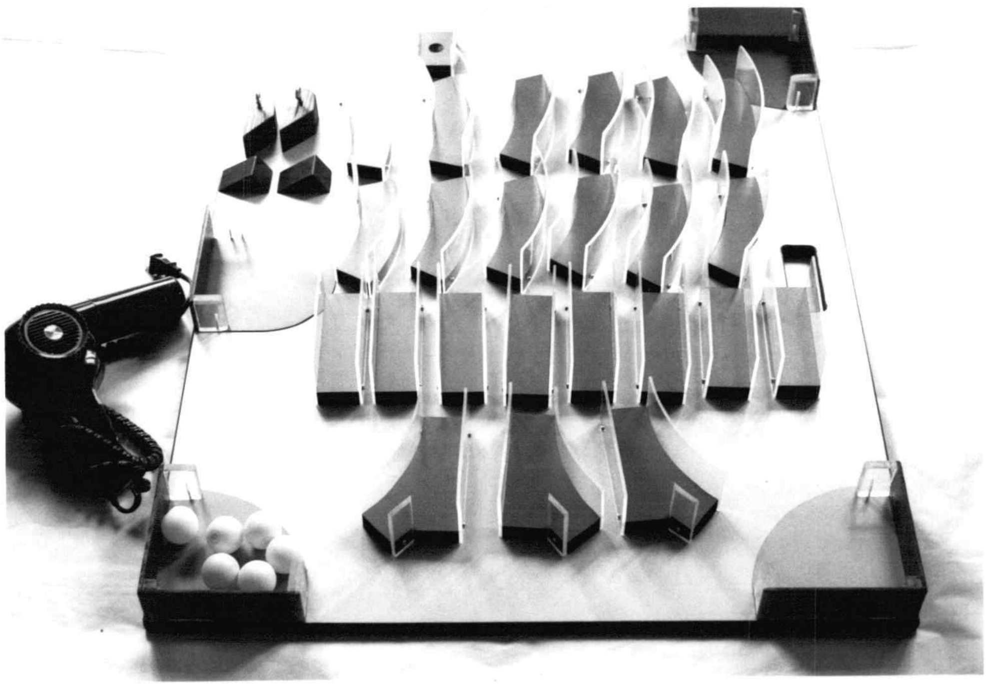
Photographs of
Condition One, Two, Three, Four



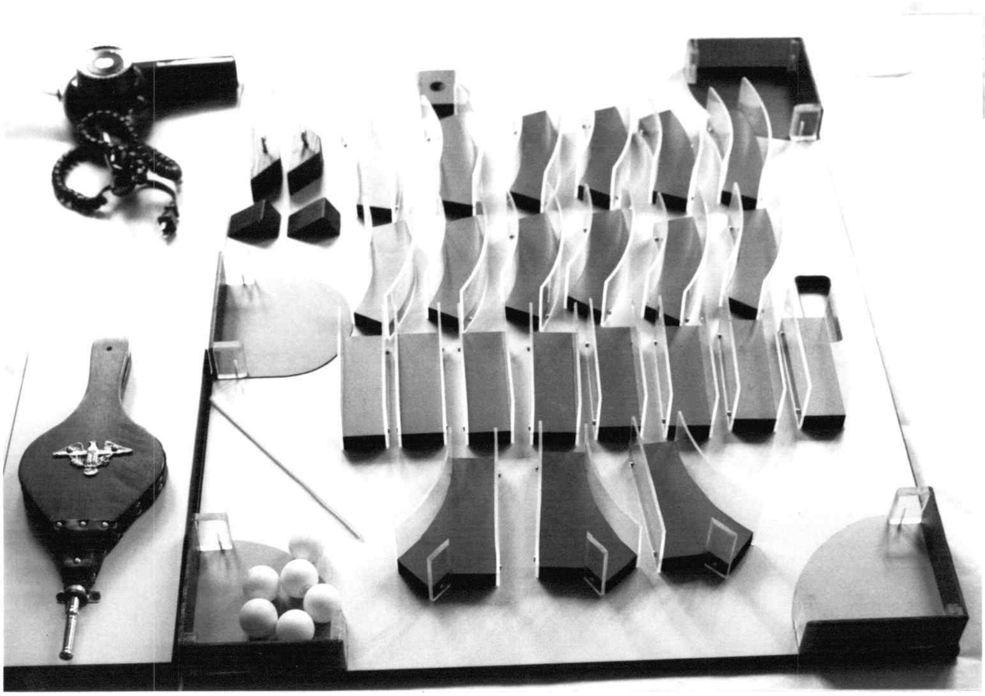
Condition One



Condition Two



Condition Three



Condition Four

Appendix D

Pilot Test Behaviors and Sample Constructions

Behaviors From Pilot Testing

Uses of Ping Pong Balls

1. One ball at a time;
2. Two balls at a time;
3. Multiple balls at a time;
4. Pushes ball(s) with hand;
5. Pushes ball(s) with air pressure devices;
6. Pushes ball(s) with mouth;
7. Places ball in entry;
8. Places ball(s) into chute past the entry; and
9. Places ball(s) in the pocket and pushes ball(s) to entry.

Uses of the Maze Pieces

1. Constructs direct route to a pocket without "Y";
2. Constructs routes to pockets with "Y" pieces;
3. Constructs loop systems, bypassing the pockets and entry;
4. Constructs dead end system that does not connect to a pocket;
5. Constructs route off the board;
6. Constructs an incline plane off the edge of the board by using a maze piece tilted on the edge of the board;
7. Constructs parallel channels from a "Y" to a pocket;
8. Constructs a route from one pocket to another pocket, bypassing the entry;
9. Stacks the maze pieces to make a two tiered chute;
10. Nest the maze pieces to make an enclosed tunnel;
11. Turns maze pieces over to make a tunnel; and
12. Constructs a maze that starts to the right or left of the entry.

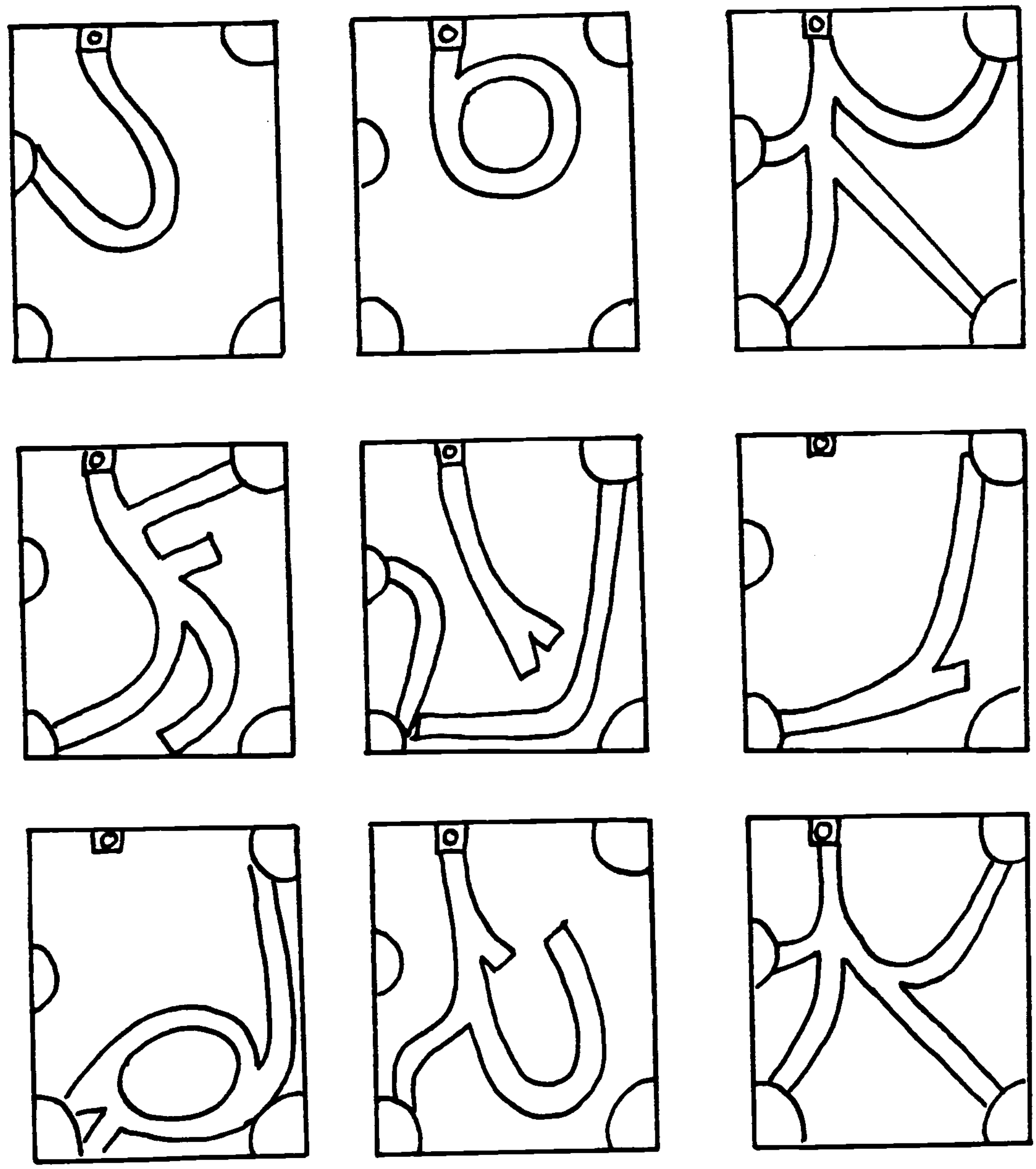
Uses of Blocks and Incline Planes

1. Places block at the end of a chute to form a pocket of own making;
2. Uses a block as an incline plane inside chute;
3. Uses the incline plane to overshoot the pocket;
4. Uses wooden blocks to channel flow of balls;
5. Uses two or more blocks inside a chute;
6. Uses two or more inclines inside a chute; and
7. Uses inclines and blocks together.

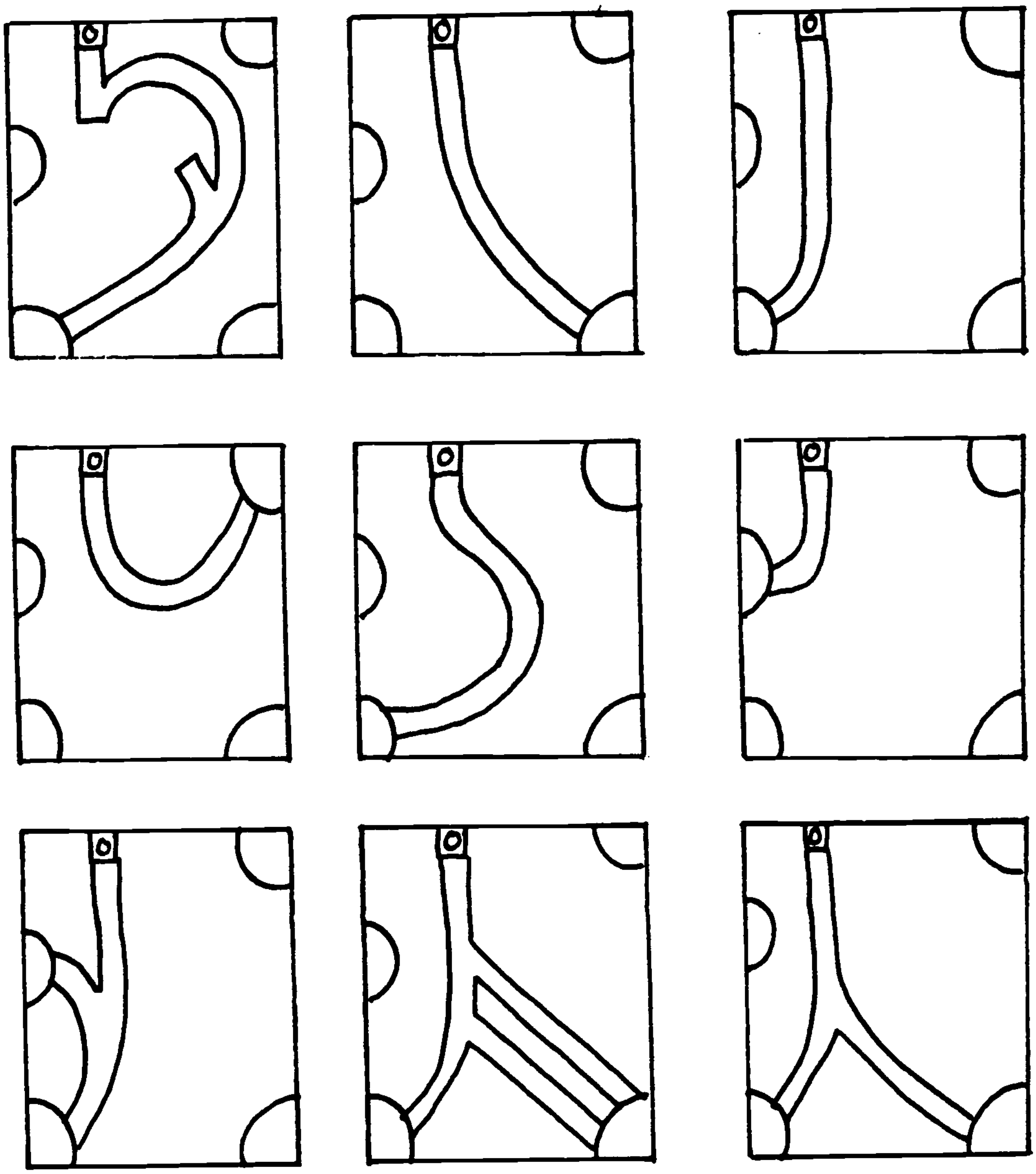
Uses of Pushing Devices

1. Uses bellow to push ball(s);
2. Uses straw to push ball(s) by blowing and pushing;
3. Uses hairdryer to push ball(s);
4. Uses more than one pusher to move the ball(s) on one trip in the chute to a pocket;
5. Changes the speed of the hairdryer; and
6. Puts the straw on the end of the bellows.

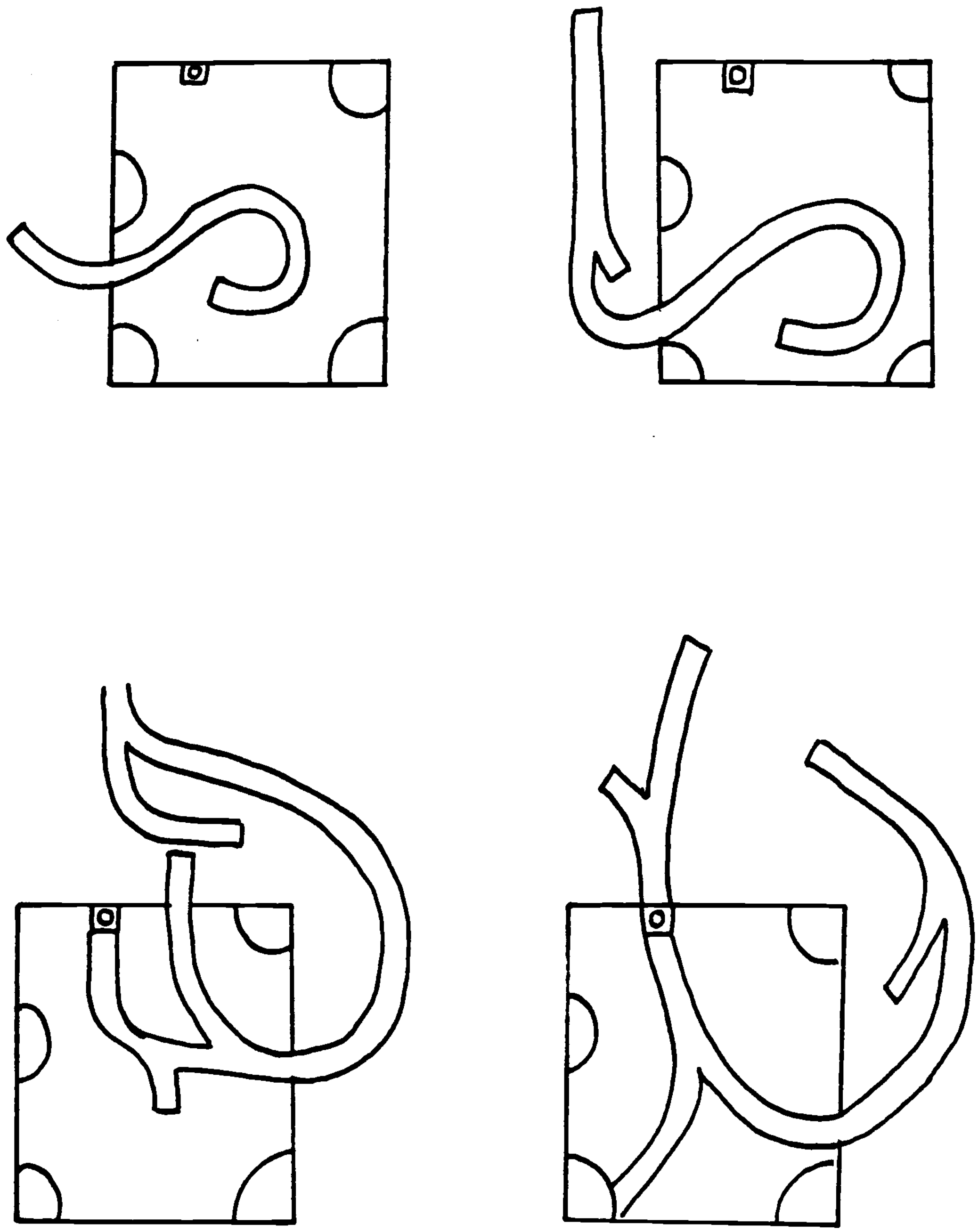
Sample Constructions from the Pilot Testing



Sample Constructions from the Pilot Testing



Sample Constructions from the Pilot Testing



Appendix E

Scoring Procedures

Scoring Procedures

Subjects received points in five areas that correspond to the hypotheses of this study. These include:

1. The number of new ideas produced (fluency).
2. The number of new ways the materials are used to carry out ideas (flexibility).
3. The number of additions or changes made to an idea (elaboration).
4. The number of new problems generated (redefinition).
5. The total of the above scores.

In addition, time spent on the task was noted. Details of the point system and a scoring sheet completes the appendix.

Time. Each subject was given up to 15 minutes to work on the problem. The length of time spent on the task was noted in minutes and seconds. Timing began after the examiner completed protocol.

Fluency. Each new single purposeful act that relates to the stated problem was counted as a new idea. Each behavior was given **one point.** Specifically, points were given for:

1. Making a ball go to a pocket without using a block or incline plane to direct it.
2. Making a ball go to a pocket by using blocks or inclines.
3. Making a ball go over an incline enroute to a pocket (this supercedes the two scores above).
4. Making a ball go to a pocket by picking up a block or incline (this superceeds the above three scores).
5. Constructing a straight chute to any pocket, including one that has been made off the board.

6. Constructing a chute with a "Y" or "Y's". Up to three different constructions are counted.
7. Moving a ball with the hairdryer.
8. Moving a ball with the bellows.
9. Moving a ball with the straw.
10. Moving a ball with hands.
11. Moving a ball with the mouth.
12. Chasing the ball with the hairdryer.
13. Chasing the ball with the bellows
14. Chasing the ball with the straw.
15. Chasing the ball with hands.
16. Chasing the ball with the mouth.

Flexibility. Each new type of purposeful behavior related to the task that changed the use of the materials was counted as flexibility. Each instance was given **one point.** Specifically, points were given for:

1. Using the straw as a blower and pusher.
2. Turing a maze piece upside down to make a tunnel.
3. Nesting maze pieces to make an enclosed chute.
4. Attempting to move the entry point.
5. Changing the speed of the hairdryer.
6. Pushing on the bellows more than once during a ball's route to a pocket.
7. Pushing or blowing with a straw more than once during a ball's route to a pocket.
8. Pushing with hands more than once during a ball's route to a pocket.
9. Using more than one ball at a time.
10. Using the entry into a chute to hold the hairdryer.
11. Using the blocks as "fences" around a pocket.

Elaboration. Each addition to, or variation of, a purposeful idea that related to the task was counted as elaboration. Each elaborative act was given **two points.** (Note, that if an idea was a new idea and not a variation or addition, it received a fluency score). Specifically, points were given for:

1. Combining any of pushers with each other, e.g., hands with the hairdyer, hands with the bellows, hands with the straw, hands with the mouth, straw with the hairdryer, etc..
2. Combining inclines and blocks together inside chutes during a ball's route to a pocket. Up to three different combinations are counted.
3. Changing the curves in a maze without changing the pocket that is the target. Up to three different changes are counted.
4. Using two or more inclines inside a chute during a ball's route to a pocket. Up to three different combinations are counted.
5. Using two or more blocks inside of a chute during a ball's route to a pocket. Up to three different combinations are counted.
6. Using the trays as decoration.
7. Using the blocks as decoration.
8. Changing a maze so that both legs of a "Y" go to a pocket.

Redefinition. Each behavior that indicates a change in the original problem was considered redefinition. **Three points** were given for each instance. (Note, that if it was a variation of the original problem, it was counted as elaboration). Specifically, points were given for:

1. Moving a ball from one pocket to another, bypassing the entry.
2. Constructing a route that goes off the board. Up to three constructions are counted.
3. Using incline planes to overshoot the pocket, causing the ball to fly out of the pocket. Up to three overshoots are counted.
4. Constructs a loop instead that bypasses the entry or a pocket causing the ball to be in a continous loop.
5. Reversing the movement of the ball from a pocket to the entry.

Total. The four scores are totaled as a composite.

Scoring Sheet

Subject ____________		FL	1	x____	=_____
Sex_____	Age________	FX	1	x____	=_____
Condition____________		E	2	x____	=_____
Time spent____________		R	3	x____	=_____
		Totals			

Fluency

RBYP	pocket without blocks
RBYP	pocket with blocks
RBYP off	moves ball over an incline inside chute
RBYP	picks block up to allow ball to pass
RBYP	constructs a straight chute to:
1 2 3	constructs a chute with a Y:
HD B S H M	moves ball with:
HD B S M	chases ball with:

Total________

Flexibility

_____	uses straw as a blower/pusher
_____	turns maze piece upside down to make tunnel
_____	nests maze piece to make an enclosed chute
_____	attempts to move the entry point
_____	changes speed of hair dryer
_____	pushes on bellows more than once on one pass
_____	blows/pushes with straw more than once on one pass
_____	pushes with hands more than once on one pass
_____	uses more than one ball at a time
_____	drops ball into cute past entry point
RBYP	uses entry into a chute to hold hair dryer
RBYP off	uses blocks as fences around pocket

Total________

Elaboration

HD B S M	combines hands with:
HD B M	combines straws with:
HD M	combines bellows with:
1 2 3	combines inclines and blocks
1 2 3	changes curves in maze w/o changing pocket
1 2 3	uses two or more inclines/ blocks within chute
_____	uses trays/blocks as overhead decoration
RBYP	changes maze so both legs of a Y go to pocket

Total__________

Combinations

	R	B	Y	P
B & I				
Multi.				

Redefinition

_____	moves ball from one pocket to another, bypassing entry
1 2 3	constructs route that goes off the board
1 2 3	uses incline blocks to overshoot pocket
_____	constructs a loop instead of directing balls to a pocket
RBYP off	reverses the movement of the ball from the pocket to entry

Total__________

Special Notes:

Appendix F

Detailed Listing of Subjects

Table F-1

Detailed Listing of Subjects
by Age, Sex, and Condition

Subject	Age (years/months)	Sex	Condition
001	6/6	F	1
002	7/0	M	1
003	6/7	M	1
004	5/3	F	1
005	4/6	F	1
006	4/6	M	1
007	4/7	M	1
008	5/5	F	1
009	5/4	M	1
010	5/11	F	1
011	4/11	F	1
012	5/0	F	1
013	6/10	M	1
014	6/8	M	1
015	4/2	M	1
016	6/6	M	1
017	4/8	M	1
018	4/7	F	1
019	5/7	M	1
020	6/3	F	1
021	5/5	F	1
022	5/9	F	1
023	6/8	F	1
024	6/8	M	1
025	6/10	M	1
026	6/4	F	1
027	5/5	M	1
028	6/1	F	1
029	4/3	M	2
030	4/6	F	2
031	4/2	M	2
032	4/11	M	2
033	5/0	F	2
034	4/11	F	2
035	4/1	F	2
036	6/8	M	2
037	4/5	M	2
038	7/3	F	2

Table Continues

Subject	Age (years/months)	Sex	Condition
039	6/8	F	2
040	5/6	F	2
041	6/1	M	2
042	5/8	F	2
043	4/11	M	2
044	4/10	F	2
045	6/11	M	2
046	6/2	M	2
047	6/8	M	2
048	7/0	F	2
049	5/10	M	2
050	7/1	M	2
051	5/10	F	2
052	5/3	M	2
053	6/5	F	2
054	5/5	M	2
055	6/8	F	2
056	5/10	M	2
057	5/8	M	3
058	5/10	M	3
059	5/3	M	3
060	7/1	F	3
061	5/2	M	3
062	6/10	F	3
063	7/0	F	3
064	5/4	F	3
065	5/10	M	3
066	5/3	F	3
067	5/1	M	3
068	7/3	M	3
069	4/11	M	3
070	6/0	F	3
071	6/6	M	3
072	6/0	M	3
073	6/2	F	3
074	4/9	M	3
075	5/3	F	3
076	5/10	M	3
077	5/7	M	3
078	6/3	F	3
079	6/6	F	3
080	4/11	F	3
081	7/0	M	3
082	4/11	F	3
083	4/6	F	3
084	5/0	F	3

Table Continues

Subject	Age (years/months)	Sex	Condition
085	4/10	F	4
086	6/11	M	4
087	6/3	F	4
088	5/4	M	4
089	6/4	M	4
090	7/5	F	4
091	6/1	F	4
092	6/4	F	4
093	5/4	M	4
094	6/6	M	4
095	6/10	M	4
096	5/4	M	4
097	5/6	F	4
098	4/11	M	4
099	4/7	M	4
100	4/9	F	4
101	6/7	F	4
102	4/11	F	4
103	5/7	M	4
104	5/3	M	4
105	6/11	M	4
106	6/11	F	4
107	5/9	M	4
108	5/9	M	4
109	4/8	F	4
110	5/4	F	4
111	5/5	F	4
112	6/0	F	4